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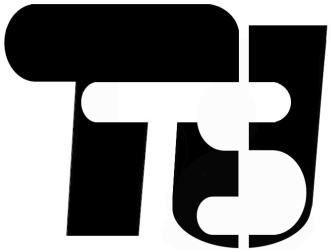

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Ritardando and Accelerando in Reflexive Innovation, or How Networks Synchronise the Tempi of Technological Innovation

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1. Times are changing...: The paradox of innovation and the problem of co-ordination

Innovation has turned out to be a fundamental imperative of modern society. Surely, in traditional societies things, beliefs, and habits are also changing with the times. But modern society differs from them under the aspect that innovation is consciously favoured and institutionally furthered. Innovation ranges as a central cultural value.

Technological innovation can be viewed as a special, but basic feature of modern industrial capitalism. Karl Marx praised its emancipatory force to free the production from the limits of nature and tradition. At the same time he criticised the consequences of capitalist innovation to bind the human work rhythm into the mechanical time regime. Technological innovation appears as the ambivalent pacemaker of production and of social history.

Joseph Schumpeter discerned the paradox of capitalist innovation. He called the double dynamics of innovation a process of "creative destruction". The innovative actions of daring entrepreneurs produce the dynamics of capitalism; the Protestant principle of timesaving and the methods of rational work organisation cannot explain its expansion and acceleration sufficiently. Capitalist innovation means creation of new combinations of methods and machines and at the same time radical devaluation of all produced values, including well-functioning machines, effective production methods, and highly qualified workforce.

Actually, we can make out symptoms of a radical change of the well-established innovation regime. Technological innovation has been till now embedded in the scientific and in the economic field. This institutional differentiation permitted a strong separation from other retarding influences and created the special tempi of scientific and of economic innovation. The tempo of natural innovation was increased. It changed from traditional "ritardando" to modern "accelerando". This process of dis-embedding innovation and of time-space-differentiation is analysed in the second part.

The globalisation of production and markets enforces the tempo of innovation. The time of the transfer and the translation between the different fields of innovation turns out as retarding bottleneck. In the economic field the tempo of innovation is accelerated by tightening up the user-producer-relations and the university-industry-relations. Just-in-time-production, strategic networks, and capitalising of knowledge are the key strategies. In the scientific field the tempo of innovation is speeded up by changing the science-technology-relations. Strategic orientation of pure science, the managerial turn of universities, and the promotion of non-academic forms of scientific knowledge production illustrate the paradigm shift in science and technology policy. But the increase of the different tempi produces problems of co-ordination and synchronisation. The "accelerando" in the distributed fields of innovation ends with a "ritardando" of the whole concerted innovation . These consequences of modernity in the field of technology creation are the subject of the third part.

Modern society knows two main mechanisms of the co-ordination of social action: markets and organisations. The liberal innovation policy of deregulation abolishes legal and bureaucratic impediments of the innovation process. But it risks to widen the gaps between the different fields and their tempos. The corporatist innovation policy of co-regulation and

de-differentiation subordinates to and concentrates the heterogeneous forces and fields on common projects and priorities. But it risks to dampen the scientific creativity and to deaden the entrepreneurial innovative capacities. A new co-ordination mechanism is wanted that reflects on the unintended consequences of markets and hierarchies. Networks seem to have this reflexive capacity. The policy of network-building succeeds in maintaining and at the same time in the tuning of the institutional and temporal differences. Innovation networks - so I shall argue in the last part - can be interpreted as the adequate institutional answer to the challenge of reflexive innovation and its problem of synchronisation. They can be seen as the core institutions of an emerging post-Schumpeterian innovation regime.

2. Tempi and places of technological innovation: from embeddedness to time-space-differentiation

Innovative action is neither limited to human beings nor to the era of modern society. But modern innovation differs from them under the aspects of durability and temporality. Apes and even birds show sometimes new patterns of behaviour. But animal associations have no memory technics like speech or technology at their disposal to mark the difference between the old and the new pattern and to reproduce the new one for a longer term. Animals' innovative behaviour cannot be made durable.

Pre-modern human societies know the flux of innovation. Their members fear its magical power. They try to integrate it in their traditions and rhythms of social life. Otherwise, if the innovations could not be captured in local customs, their authors were excommunicated from the community or even burnt on the stake. Innovative action was treated as a type of deviant behaviour like criminal or insane action which threatened the institutions and the solidarity of traditional society.

In spite of the spectacular sanctions of innovative action for instance in the Middle Ages, we have learnt in the last decades, that feudal society was rich in technological innovations. They took place in agriculture and warfare, under miners and manual workers, constructing cathedrals and ships. They culminated in the 13th century so that some medieval students even speak of an early or proto-industrial revolution. But in general, technological development was characterised by a calm, cumulative, and continuous stream of hardly perceptible changes. We all know the well-documented evolution of the stirrup and the plough (see White). This "longue durée" of pre-modern innovation knew neither any individual inventor nor any significant rupture. The waves of innovation were smoothed out by the institutional orders of the church, the chivalry, and the city guild. The innovative action remained integrated in the collective practices of artisans and artists. The consequences of inquiry and invention were tamed by the conventions and norms of the trades. We can say that this type of premodern innovation was embedded in tradition. Its tempo can be marked as "ritardando".

Modern innovation emerges with processes of dis-embedding and re-embedding innovative action. Inquiry is emphasised in comparison to routine action. Creative activities are separated and bundled into special roles. Innovators free themselves from the traditional

bonds of trade and guilds in escaping the local control of cities. Mills outside the city walls and mines in distance to the castle complex grew to the preferred places of technological innovation. The construction and strengthening of pump mechanism was for instance not any longer integrated in the local routine work of mining, but became a different task of the "mechanici", the fore-runners of the modern engineers, who collected and compared data and machine descriptions from different places. Awareness changed from local references to inter-local references. This inter-locality established a new frame of self-reference which could gain a relative autonomy from traditional institutions. Mechanical innovation referred to mechanical innovations: the innovative actions became recursive. It started with the books about mechanics and machinations and lead to the disciplines of engineering. Dis-embedded from traditions and local authorities modern innovation developed its own rhythm and could increase speed. Dis-embedding innovative action indicates the tempo of "accelerando".

The rhythm of pre-modern innovation can be described by the formula: routine action - routine action - innovative action; routine action - routine action - innovative action; and so on. Routine actions are dominant. If a problems arises, innovative action may emerge, but it will be integrated in the routine-dominated rhythm or completely extinguished. The rhythm of modern innovation is however more vibrant: innovative action - routine action - routine action; innovative action - routine action - routine action; and so on. Now the first bar is emphasised. The innovative actions are connected, and a new rhythm emerges. This rhythm is accelerated like in the Viennese Waltz, though the elements remain the same. The change of tempo was achieved by only changing the inter-punctuation.

My description of the dis-embedding follows widely accepted aspects of modernisation theory. Modern societies differ from pre-modern ones that they break with the tradition and that they differentiate between spheres of action in order to rationalise it and to raise its capacity. For instance, economic action is dissolved from the moral bonds of household economy. Political action frees itself gradually from religious legitimisation. Scientific action emancipates from the authority of the church and of ancient texts. And technological action too broke with tradition and was separated from the routines of craft work.

My description deviates from functionalism's view of differentiation insofar as the emergence of social subsystems is reconstructed as an actor-mediated and historical process of institutionalisation. Systems of recursive action are generated at local places and get globalised by processes of transfer and imitation. Differences between the genesis of institutions (see Wagner) and between the national institutional arrangements are seen as important critical factors.

Under this institutional perspective the process of re-embedding technological innovation gains great significance. It is true that technological innovative action was dis-embedded from tradition, but in comparison with the other types of action it did not develop one special system of innovation. Modern innovation was re-embedded into two other social subsystems: technological innovation entered a symbiosis with the scientific research system and with the economic production system.

From the rise of modern sciences technological innovation has been narrowly enmeshed with inquiry and scientific research. In Renaissance Italy "experimental philosophy" was generated out of the crossing of humanistic academic culture with the technological culture of artisans and artist-engineers (see Zilsel). The new sciences furthered by the London

Royal Society heavily relied upon the experimental demonstration of scientific laws in presence of a distinguished group of gentlemen (see Shapin/Schaffer). Also later on scientific development was closely connected with progresses in instrument-making and in the construction of bigger and more sophisticated new experimental facilities.

It is obvious that technological innovation became a basic feature of economic action in industrial capitalism. Process innovations are used to minimise production costs. Product innovations are pushed to open new markets. The embedding of technological innovation in economic production takes such a strength that the definitions of technological efficiency and economic efficiency show merely any difference. Karl Marx and Max Weber unanimously argue that the courses of technological development were in the long run determined by economy.

Technological innovation was re-embedded in the scientific and ín the economic sphere. Technologies developed at different places with different tempi. We remember that innovative action, if completely unbound, radically destroys the good for the better. In order to use the achievements of accelerated innovation, institutions are needed which regulate the change from the non-evaluated new to the evaluated new. This process does not refer to a substantial innovation or embetterment - who should define the measure and from which standpoint? -, but to a formal mechanism of evaluating something profane to enter the highly-evaluated sphere of the "archive" (see Groys). The museems of art, for instance, regulate the stream of artistic innovation. Even the formerly primitive, wild or anti-aethetic artist action is turned into evaluated art when it crosses the barriers of the museeum.

Which institution can be identified to do the same task with concern to technological innovation? Because technological innovation is interwoven with scientific and economic production, there are to be found several places. The peer-reviewed publication regulates the stream of the scientific innovation. The state-of-the-art documented in handbooks and on conferences regulates the engineering innovation. The office of patents does the same to the practical technological innovation. The corporations decide on the rhythm of economical innovation. We see that the tempi and places of modern technological innovation are highly differentiated.

In science, the destructive feature of technological innovation was tamed by giving priority to the theoretical argument. As long as an experimental innovation cannot be explained in the frame of the theoretical paradigm it cannot gain power over the scientific development. For a long time, technology was kept in the role of the hand maiden of science. Following this line of argumentation one distinguished pure science from applied science. The tempo of innovation was bound to the change of theories. The standard course of innovation took part from discovery and aimed at appliance.

In industrial economy, the ambivalence of technological innovation was controlled by a set of tacit practices and regulatory institutions. A destructive speed of innovation could be slowed down by buying up patents and by secret marketing agreements. Corporations could gain influence on its direction by establishing research and development departments of their own. and by organising joined industrial laboratories. The mass producers sought to profit from technological innovation, but at the same time to control its rhythm. They separated the technological development from routine production activities and subordinated technological innovation under the economically calculated change of

products. As consequence a product cycle of three to six years emerged. All activities, also the feed-back from the production line and from customers, were adapted to this time interval. The standard course of innovation started from industrial research and development and aimed at the cyclical change of products and of the production line.

On the level of the whole industry, long waves of technological innovation could be observed. They are unintended consequences of innovative action in science and industry. During times of normal industrial technological development, radical innovations are put aside because of their destructive character. Defensive innovations are favoured. But when the established techno-economic paradigm (Perez/Freeman) has crossed its peak and when markets begin to stagnate, then scientific inventors and inventor-entrepreneurs get a chance to surmount the obstacles against radical destructive innovation and to globalise their local achievement. Then the take-off of a new Schumpeterian innovation cycle can be expected. New industries emerge around them and their products. Some traditional industries disappear, some adapt the new technology and change their production. If we follow the economic growth data of Kuznets or of Kondratieff, the life times of these long innovation cycles are about forty to fifty years, beginning with its first upswing in eighteen hundred and starting the fourth Kondratieff cycle in nineteen hundred and fifty.

One has not to accept this comprehensive theory of the cyclical co-evolution of economic and technological development completely, but nearly all theoretical approaches share the assumption of an evolutionary cyclical development of technological innovation. Many of them are excellently integrated in the model of technology cycles in which "eras of ferment" and "eras of incremental change" alternate with each other (see Tushman/Rosenkopf 1992: 317). Technological discontinuity arises and variation predominates in the era of ferment, whereas technological continuity is established by the selection and retention of a dominant design.

The discontinuous cyclical rhythm of modern innovation differs significantly from the continuous cumulative rhythm of pre-modern technological change. The difference between modern and pre-modern innovation mainly concerns two aspects: In modernity, the new is exlicitly marked against the old, the modern is highly evaluated over the traditional, on the one side; the innovation is incorporated in new techno-structures, ranging from new products to large technological systems and technological infrastructures which give durability and resistance against change to the innovation, on the other side.

We can summarise our considerations: In modernity, technological innovation gained speed because it was dis-embedded from trades and traditions. It was re-embedded in the fields of scientific and of economic production. These fields can be seen as different time zones constituted by various dominant time perspectives.

3. Consequences of modernity: reflexive innovation

Technological innovation was accelerated, but in a socially distributed system of technology creation. That means that the tempo and the direction of technological development was unbound from local traditions, but that they now depended on a plurality

of institutional fields with their different time horizons, like science, economy, and the state.

In science, a mutual interdependency between scientific and technological innovation can be observed. As consequence, what was called "pure science" coincides more and more with "practical technology", like in the "technosciences" of nuclear physics and molecular biology or in the "high technologies" of computer science and artificial intelligence; the risk of experimentation that seemed until now to be limited to the laboratory spreads to all places in society where the new technologies are implemented (see Krohn/Weyer). The scientification of technologies raises increasing problems of their practical use. To close the widening gap between scientific technology and practical use the university-industry-relations are tightened up.

In economy, the wedding of industry and technological innovation leads to the rise of science-based industries and to the industrial organisation and orientation of research and development (see Noble). As a consequence, industrial production leaves the track of its standard product cycles and gets under the imperative of unbound technological innovation. Price competition turns into quality competition. To keep with the pace of technological innovation corporations look for a closer cooperation between developers and producers and between producers and users.

In politics, states always knew how to reap the benefits of technological innovation. Modern nation-states mainly win their economic competitiveness and their military power from technological achievements. To keep their position in the world-system they are now forced to identify and sponsor technological innovations in strategical fields. The governments have to seek more advice and assessment from scientific, technological and economic experts. To get the information about the technological trends and to gain influence on the different corporate actors neo-corporatistic relations between science, industry and the state are installed.

We can see that all these institutional changes contributed to the acceleration of technological innovation in each field. The establishment of a standard sequence from scientific discovery over technological invention to economic innovation regulated the unruly stream of innovation. Institutional differentiation attributed a certain role to each participant of the process. Simple feed-back processes between science and technology or between producers and users of new technology stabilised the paths of technological developments. The course a technological innovation would take could be expected. In the same way as the welfare state created a standard course of a worker‘s life in the sixties and seventies, this socially distributed system of technology generation succeeded in establishing an efficient innovation regime and a standard course of innovation.

But since some decades this modern innovation regime like the welfare state shows signs of crises and of dissolution. Let me give some examples on the institutional level:

- Scientific knowledge production emigrates from the universities and abandons the classical boundaries of scientific disciplines.

- The boundaries between pure science and applied science or technology are crumbling. Basic technological research may be rewarded with Nobel prizes; and scientific discoveries may be suitable to be protected by patents and to be exploited commercially.

- The feed-back mechanism in technological education from practical experiences is interrupted by the increasing scientification and academisation of the engineering professions.

- The evolved producer-user-relations in industry are decaying under the pressure of global markets and under the imperative of radical changes of the techno-economic paradigms. The advantages of the trust-based relations in German mechanical engineering industry are turning into barriers to flexible adaptation to different users and to the requirements of the globalized competition.

- The techno-economic paradigm of mass-production is loosing ground in many industries without the rise of a new dominant mode of production.

- Neither big corporations nor middle-sized enterprises remain the strategical places of technological innovation. More and more intermediary institutions participate in the process of technology creation.

- The state looses its central position in innovation policy-making. The plurality of participants in the innovation process requires a de-centralized governance structure. The state undertakes the role of an mediator and moderator.

These institutional changes are marked by three common denominators: contingency, plurality, and glocality. Contingency means, that there cannot be any longer expected a fixed way how to initiate, organise or to evaluate technological innovation. Science cannot garantuee the harmlessness of an innovation, technology cannot abolish the ambivalence of techniques, expertise has lost its innocence. The rising consciousness of contingency is a product of the successful reduction of contingency by science and technology. The more we know about intended effects, the less we know about the non-intended side-effects.

Plurality means that there cannot be identified any center or central actor in the technological development. Concerning this issue we share the post-modern diagnosis that we live in worlds with a plurality of rationality standards and that there exists no priviledged way to assess technological innovations. Additionally, we have to dissolve society into a plurality of fields and forces of action, separating from one another and crossing with one another. The myths of a capitalist determination or of a functionalist system differentiation have to be given up in favour of a historical and institutional view of human association.

Glocality indicates a new spatial relationship: the local and the global cannot any longer be separated. Local niches are disappearing and cannot be protected against global influences. Local decisions have to reflect on global implications: scientific experiments and their implications, like the cloned Scotish sheep, cannot be restricted to scientific communities; technological inventions, like the atomic bomb, cannot be limited to an exclusive group of nations; effects of technological hazards, like the radioactive cloud from the Tschernobyl accident, does not stop at the national frontiers. The globalization of

production and markets and the worldwide webs of communication enforce the tempo and the risks of technological innovation.

What are the consequences of these institutional changes on the level of the individual course of technological innovation? Can we observe empirical indicators how the rise of contingency, the mode of more distributed plurality, and the worsening of glocality have impacts on the patterns of technological developments?

- The identity of the final technology has become multiple and more uncertain than before: the tempo of innovation raises the options. At the beginning one does not know, but has to decide whether to design a working machine with computer aid or a computer system with a periphery of working machines. Needs the internet communication an extra network computer or is the multimedia computer the best solution or should be taken a converted televison set?

- The feed-back-informations have to include a greater plurality of contexts and have to be done more simultanously. The simple recoursive processes between producer and user are not any longer sufficient, but a multiplicity of aspects has now to be reflected on to gain the position of a successful innovation. Besides the production engineering criteria and the user requirements there has to be regarded the compatibility with the established technological systems, the conditions of national or european sponsoring, the constitutional and legal compatibility, the environmental impacts, and the social aceptability of the final product.

- Passage points in the technology‘s biography between the scientific, the economic and the political field have become more critical: the help of mediating agencies is needed to overcome these precarious interfaces. The requirements to translate between various institutional fields are grown. The necessity to negotiate the technical standards between different actors has increased.

- The emancipation of an innovation‘s course from narrow regional structures and from traditional trajectories of technological development is pushed forward: this "individualisation" of innovation patterns opens the opportunity to have more choices at the rise of a new technology, but the risks of failure are also higher because of the missing standard path with all its certainties.

- The time interval between two generations of a technology becomes shorter and the inter-generational difference is growing: technological development is accelerated when unbound from the institutionalised course. This phenomen is excellently demonstrated by the fast change of software paradigms from writing to growing (see Pflüger 1996) and the even faster succession of one software-version by another one. Well-functioning technologies are becoming obsolete, before people have learnt to handle them with routine.

Multiplicity, individuality, recoursivity, and rapidity mark the emerging course of reflexive innovation. Multiplicity results from a radical institutional dis-embedding and a raising

consciousness of contingency. It is a consequence of modernity. The dissolution of standard courses enables more individuality and alternity in technology design, on the one side. But on the other side, the plurality of participants and contexts asks for more recoursive processes with different agencies and at different times. Glocality leads to an enormous time compression (see Harvey) and increases the rapidity. But the faster the changes in the different phases and fields of innovation, the greater the problems of synchronisation. The many "accelerandos" in the distributed fields of innovation end with a "ritardando" of the whole concerted innovation. A new innovation regime has to be found that may meet this challenge of reflexive innovation.

4. The rise of a post-Schumpeterian innovation regime: The agency of networks

In the second part, we analysed the time-space-differentiation in modern society and its impact on the acceleration of technological innovation. In the third part, we argued that contingency, plurality, and glocality in the innovation process are increased in a way that the modern innovation regime crumbles and shows signs of crises. The radical dis-embedding of innovation produces multiplicity, individuality, greater recoursivity, and rapidity in the course of a technology‘s life. We have called this emerging type of technology generation reflexive innovation. It raises new problems of co-ordination between the institutional fields and problems of synchronisation between the different time zones. Which social mechanism would be able to take over this task of tuning the different tempi of technological innovation?

Modern society relies mainly on two mechanisms to co-ordinate social action: markets and organisations. Markets are efficient means to suit a set of products to a set of needs. With regard to time, the different tempi of production and of consumption are concerted automatically with the act of exchange. Insofar markets are also extremely efficient means of time compression. But markets require a certain calculability of the critical events. They fail when the uncertainties are growing and when the time horizons are expanding. That is why the liberal type of innovation policy of de-regulation cannot be successful. Legal and bureaucratic impediments of the innovation are, however, abolished and the tempo of innovation is accelerated, but at the same time the gaps between the different fields and their tempos are widened and the uncertainties are increases.

Organisations have proved to be reliable co-ordinators of heterogeneous tasks and time perspectives. They are successful mechanisms of co-ordination because they are able to establish calculability and certainty in their limits. They create their own order and subordinate people, things, and symbols under the procedural rationality. With regard to time, organisations have shown to be efficient means of timetabling and time-storage. But organisations fail when differences should be maintained and the time horizon should be kept open. Therefore the neo-corporatist type of innovation policy of regulation and de-differentiation will only show a limited success. It subordinates the heterogeneous forces and fields under common projects and priorities. This alignment of different visions and

tempi in technology development risks to dampen the scientific creativity and to deaden the entrepreneurial innovative capacities.

A new co-ordination mechanism is wanted that avoids the disadvantages and that combines the advantages of the two other ones. Networks seem to have this reflexive capacity. They are based on negotiation and trust relations (see Powell 1990, Mayntz 1992). Negotiation maintains the flexibility of markets without showing their indifference to goods and actors. Trust relations reduce uncertainties without aligning the differences as radically as organisations do. With regard to time, networks admit different tempi and an open time horizon. This feature makes them to superior means of polyphonial time synchronisation. A reflexive type of innovation policy should be based on network-building. It will succeed as well in maintaining as in the tuning of the institutional and temporal differences.

Networks are not a completely new social mechanism of co-ordination. In a certain way they are one of the oldest ways of social organisation. Clans and kinships are constituted by personal networks. Reciprocity has always been a third mode besides redistribution and markets to co-ordinate the economic activities (see Polanyi). With the rise of modernity networks lost their weight in comparison to the more abstract mechanisms of markets and organisations. But they didn't disappear. If we actually speak of networks, we mostly address inter-organisational networks. Strategic networks between corporations nowadays are initiated to start joint ventures in highly uncertain field and at the same time to compete in the conventional fields. Policy-networks emerge to uphold the chance to get a highly complex policy field regulated. A non-government governance structure rises between the participating collective actors.

Returning to the socially distributed innovation system we can now observe that the relations between the different organisations are changing. Cooperations between science and industry are not only managed by occasionally buying patents or by continually organising research and development, but by establishing medium-term partnerships. If this partnerships go beyond simple recoursive relations between technology producers and users or between university laboratories and corporations, if they encompass more actors from different fields, then we define them as innovation networks (see Freeman 1991; Kowol/Krohn. 1995). These innovation networks seem to be the adequate institutional answer to the challenges of reflexive innovation and its problems of synchronisation. The agency in the innovation process shifts from the particular organisations to the innovation network. If neither the innovative entrepreneur, nor the bureaucracy of big science, nor the capitalist corporation is any longer the principal agent of technological innovation, then the new era of a post-Schumpeterian innovation regime is coming. Networking between the heterogeneous agents in a socially distributed system can be seen as its basic principle. With regard to time, networks allow different tempi of innovation in the various fields. they are capable to synchronise them into a poly-rhythmically concerted symphony, just as the change between slow and quick tempi enriches the colour and the tension in a piece of musique.

Literaturverzeichnis

Arthur, B., 1989: Competing Technologies, Increasing Returns, and Lock-in by Historical Events; in: Economic Journal, 99, 116-31

Asdonk, J./Bredeweg, U./Kowol, U., 1991: Innovation als rekursiver Prozeá. Ein theoretisches Modell zur Technikgenese im Bereich der Produktionstechnik; in: Zeitschrift für Soziologie, 20, 290-304

Beck, U., 1986: Risikogesellschaft, Frankfurt/M: Suhrkamp

Beck, U., 1993: Die Erfindung des Politischen, Frankfurt/M.: Suhrkamp

Beck, U., 1994: The Reinvention of Politics: Towards a Theory of Reflexive Modernization; in: Beck, U./Giddens, A./Lash, S., 1-55

Beck, U./Giddens, A./Lash, S., 1994: Reflexive Modernization, Cambridge: Polity

Belt, H.v.d./Rip, A., 1988: The Nelso-Winter-Dosi-Model and Synthetic Dye Chemistry; in: Bijker, W./Hughes, T./Pinch, T., 135-58

Bijker, W./Hughes, T./Pinch, T. (eds), 1988: The Social Construction of Technological Systems, Cambridge, MA: MIT

Callon, M., 1993: Variety and Irreversability in Networks of Technique Conception and Adoption; in: Foray, D./Freeman, C., 232-69

David, P., 1993: Path-Dependence and Predictability in Dynamic Systems with Local Network Externalities: A Paradigm for Historical Economics; in: Foray, D./Freeman, C., 208-31

Dierkes, M./Hoffmann, U./Marz, L., 1992: Leitbild und Technik. Zur Entstehung und Steuerung technischer Innovationen, Berlin: Sigma

Dosi, G., 1982: Technological Paradigms and Technological Trajectories; in: Research Policy, 11: 147-62

Dosi, G./Freeman, C./Nelson, R./Silverberg, G./Soete, L. (eds), 1988: Technical Change and Economic Theory, London: Pinters

Foray, D./Freeman, C. (eds): Technology and the Wealth of Nations, London: OECD

Freeman, C./Perez, C., 1986: The Diffusion of Technological Innovations and Changes of Techno-Economic Paradigm; paper presented at the Conference on Innovation Diffusion, Venedig

Freeman, C., 1988: Introduction, in: Dosi, G. u.a., 1-12

Freeman, C., 1991: Networks of Innovation: A Synthesis of Research Issues; in: Research Policy, 20, 499-514

Frost, P./Egri, C., 1991: The Political Process of Innovation; in. Research in Organization Behavior, 13, 229-95

Funtowicz, S./Ravetz, J., 1993: Science for the Post-Normal Age; in: Futures, Sept., 739-55

Gibbons, M./Limoges, C./Nowotny, H./Schwartzman, S./Scott, P/Trow, P., 1994: The New Production of Knowledge. The Dynamics of Science and Research in Contemporary Societies, London: Sage

Giddens, A., 1988: Die Konstitution der Gesellschaft, Frankfurt/M: Campus

Giddens, A., 1993: Tradition in der post-traditionalen Gesellschaft, Soziale Welt 44, 4, 445-85

Giddens, A., 1995: Konsequenzen der Moderne, Frankfurt/M: Suhrkamp

Groys, B, 1992: šber das Neue. Versuch einer Kulturökonomie, München: Hanser

Hakansson, H., (ed.) 1987: Industrial Technological Development. A Network Approach, London: Croom Helm

Hirsch-Kreinsen, H., 1993: NC-Entwicklung als gesellschaftlicher Prozeá. Amerikanische und deutsche Innovationsmuster der Fertigungstechnik, Frankfurt/M: Campus

Hirsch-Kreinsen, H., 1994: Innovationspotentiale und Innovationsprobleme des Werkzeugmaschinenbaus. Zum Verh"ltnis von Verwissenschaftlichung und industrieller Praxis; in: WSI-Mitteilungen, 2, 94-102
Hirsch-Kreinsen, H., 1995: Produktionstechnische Entwicklung. Historischer Wandel und aktuelle Probleme (Sektionsvortrag), erscheint demnächst in: Technik und Gesellschaft. Jahrbuch 9, Frankfurt/M: Campus
Hodges, A., 1989: Alan Turing, Enigma, Berlin: Kammerer & Unverzagt
Hughes, T.S., 1976: The Development Phase of Technological Change; in: Technology and Culture, 17, 423-31

Jewkes, J./Sawers, D./Stillerman, R., 1959: The Sources of Invention, New York: St. Martin`s Press
Jürgens, U./Naschold, F., 1994: Arbeits- und industriepolitische Entwicklungsengpässe der deutschen Industrie in den neunziger Jahren; in: Zapf, W./Dierkes, M. (Hg.): Institutionen Vergleich und Institutionendynamik, WZB-Jahrbuch, Berlin: Sigma, 239-70

Keck, O., 1993: The National System for Technical Innovation in Germany; in: Nelson, R., 115-55
Kern, H./Sabel, C., 1994: Verblaáte Tugenden - Zur Krise des "deutschen Produktionsmodells"; in: Beckenbach, N./Treeck, W.v. (Hg.): Umbrüche gesellschaftlicher Arbeit, Soziale Welt, SB 9, Göttingen: Schwartz, 605-24
Knorr Cetina, K., 1995: Laboratory Studies: The Cultural Approach to the Study of Science; in: Jasanoff, S./Markle, G./Petersen, J./Pinch, T. (eds): Handbook of Science and Technology Studies, Thousand Oaks: Sage, 140-66
Kohli, M., 1986: Gesellschaftszeit und Lebenszeit. Der Lebenslauf im Strukturwandel der Moderne; in: Berger, J., 183-208
Kowol, U./Krohn, W., 1995: Innovationsnetzwerke. Ein Modell der Technikgenese, in: Technik und Gesellschaft. Jahrbuch 8, Frankfurt/M: Campus, 77-105

Lash, S., 1994: Reflexivity and its Doubles: Structure, Aethetics, Community; in: Beck, U./Giddens, A./Lash,S.: 110-72
Latour, B., 1987: Science in Action: How to Follow Scientists and Engineers Through Society, Cambridge, MA: Harvard U.P.
Luhmann, N., 1987: Soziologische Aufklärung 4: Beiträge zur funktionalen Differenzierung der Gesellschaft, Opladen: Westdeutscher Verlag
Luhmann, N., 1992: Beobachtungen der Moderne, Opladen: Westdeutscher Verlag
Lundvall, B.-A., 1988: Innovation as an Interactive Process: From User-Producer-Interaction to the National System of Innovation; in: Dosi, G. u.a., 349-69
Lundvall, B.-A., 1993: User-Producer Relationships, National Systems of Innovation and Internationalization; in: Foray, D./Freeman, C., 277-300

Nelson, R./Winter, S., 1977: In Search of a Useful Theory of Innovation; in: Research Policy, 6: 36-76
Nelson, R. (ed.), 1993: National Innovation Systems. A Comparative Analysis, Oxford: University Press
Noble, D.F., 1977: America by Design. Science, Technology and the Rise of Corporate Capitalism, New York: Alfred A. Knopf

Powell, W., 1990: Neither Market Nor Hierarchy: Network Forms of Organization; in: Research in Organization Behavior, 12, 295-336

Rammert, W., 1993: Technik aus soziologischer Perspektive, Opladen: Westdeutscher Verlag
Rammert, W., 1995: Von der Informatik zur Kinematik: Konzeptuelle Wurzeln der Hochtechnologie im sozialen Kontext; in: ders. (Hg.): Soziologie und künstliche Intelligenz. Produkte und Probleme einer Hochtechnologie, Frankfurt/M: Campus, 65-110
Rammert, W., 1997: New Rules of Sociological Method: Rethinking Technology Studies; in: British Journal of Sociology, vo. 48, 2, 171-191
Reich, L., 1985: The Making of American Industrial Research, Cambridge: University Press

Schumpeter, J., 1912: Theorie der wirtschaftlichen Entwicklung, Berlin
Schumpeter, J., 1961: Konjunkturzyklen, G"ttingen: Vandenhoeck & Ruprecht (zuerst 1939)
Schumpeter, J., 1946: Kapitalismus, Sozialismus und Demokratie, Bern: Francke (zuerst 1942)
Sydow, J., 1992: Strategische Netzwerke - Evaluation und Organisation, Wiesbaden: Gabler
Sydow, J./Windeler, A. (Hg.) 1994: Management interorganisationaler Beziehungen, Opladen: Westdeutscher Verlag

Technik und Gesellschaft 1994: Konstruktion und Evolution von Technik, Jahrbuch 7, hg. v. Rammert, W./Bechmann, G., Frankfurt/M: Campus
Technik und Gesellschaft 1995: Theoriebausteine der Techniksoziologie, Jahrbuch 8, hg. von Halfmann, J.u.a., Frankfurt/M: Campus
Tushman, M./Rosenkopf, L., 1992: Organizational Determinants of Technological Change: Towards a Sociology of Technological Evolution; in: Research in Organization Behavior, 14, 311-47

Van den Ven, A., 1993: The Emergence of an Industrial Infrastructure for Technological Innovation; in: Journal of Comparative Economics, 17, 338-65
Van de Ven, A./Garud, R., 1994: The Coevolution of Technical and Institutional Events in the Development of an Innovation; in: Baum, J./Singh, J (eds): Evolutionary Dynamics of Organizations, Oxford: University Press, 425-443
Vernon; R., 1966: International Investment and International Trade in the Product Cycle; in: Quarterly Journal of Economics, 80, 190-207

Weick, C., 1990: Technology as Equivoque. Sense-Making in New Technologies; in: Goodman, P./Sproull, L. (eds): Technology and Organizations, San Francisco: Jossey-Bars
White, L., 1962: Medieval Technology and Social Change. Oxford University Press
Womack, J:/Jones, D./Roos, D., 1991: Die zweite Revolution in der Autoindustrie, Frankfurt/M: Campus